

To help meet the growing world demand for chemicals and consumer products, new methods are being developed to use biobased products as additional sources of industrial feedstocks.



PROFILE

Agriculture Industry

UTILIZATION OF WORLD BIOMASS RESOURCES



Total World Biomass Production
 6.9×10^{17} kcal/yr

Source: Plant/Crop-Based Renewable Resources 2020

BIOBASED PRODUCTS

The focus of OIT's Agriculture program is the biobased products industry. The objective of this emerging industry is to create new products from the abundant renewable resources found in agriculture, forests, and pasture lands. Chemicals that can be used to make plastics, for example, could be made from corn, soybeans, or wood. Biobased products are created through the combined efforts of many industrial communities, including agriculture, forestry, chemicals, and biotechnology.

Many of the products that could be made from biobased products are now made from petroleum (e.g., petrochemicals). Plant derived materials will be one way to supplement petroleum and meet increasing worldwide demand for consumer goods.

Renewable agricultural resources have historically been used primarily for food, animal feed, and fibers. Excluding forest products, bio-based resources currently constitute less than 5% of all raw materials used as industrial feedstocks.

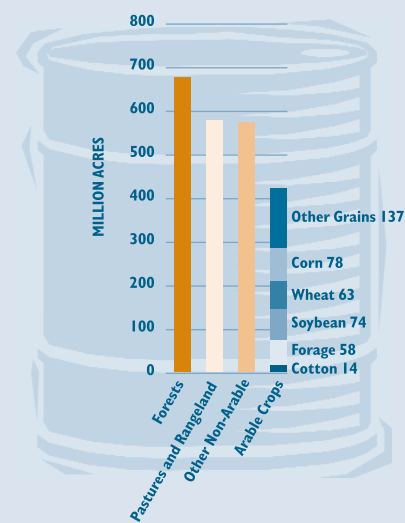
The lack of economical chemical conversion methods and difficulties in manipulating the “structure” of plant materials has often made biobased feedstocks a high-cost option for manufacturers. However, in cases where economical processes do exist, plant-derived production costs are nearly equal to those for conventional production. For example, surfactants, which are used in household soaps and detergents, can be produced from plant-derived material at the same cost per pound (\$0.45/lb) as petrochemical feedstocks. About 35% of surfactants are currently produced from plant resources. In order to increase the use of biobased products, methods must be developed to better separate and synthesize plant components into materials that can be easily and economically used in industrial processes.

MATERIALS AND PRODUCTS

The potential for using plants and crops as raw materials is large. Some plants and crops already serve as feedstocks to a limited extent in a variety of industries. Soybeans are used to make inks, paints, oils, lubricants, and cleaning products. Furniture, particleboard, and other building materials are fabricated from crops such as wheat straw and kenaf. Many industrial processes also use a number of chemical compounds that are extracted from plants and crops, including starches, proteins, fatty acids, and isoprene compounds. Other exciting possibilities, such as using corn to make polylacticacids for polymers, are also on the near horizon.

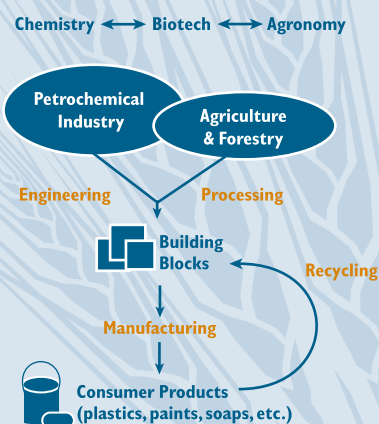
Great potential also exists in harvest wastes. For example, cotton wastes are being used to produce activated carbon and products for absorbing oil spills. Similar possibilities exist for crops that are already grown for food, such as corn, soybeans, wheat, and sorghum; harvest waste currently left in the fields could be used as industrial feedstocks.

PLANT/CROP-BASED RESOURCES IN THE UNITED STATES



Source: Plant/Crop-Based Renewable Resources 2020

THE BIOBASED PRODUCTS INDUSTRY



INDUSTRIAL USE OF RENEWABLE RESOURCES

Inputs	Million tons used per year	Uses
Wood	80.9	Paper, paperboard, lignocellulose composites
Industrial starch	3.0	Adhesives, polymers, resins
Vegetable oils	1.0	Surfactants, inks, paints, resins
Natural rubber	1.0	Tires, household goods
Wood extractives	0.9	Oils, gums
Cellulose	0.5	Textile fibers, polymers
Lignin	0.2	Adhesives, tanning, vanillin

Source: The Carbohydrate Economy, D. Morris and D. Ahmed, 1992



Industry Vision and Roadmap

PLANT/CROP-BASED RENEWABLE RESOURCES INDUSTRY VISION

In 1996, the National Corn Growers Association initiated a workshop to begin work on a strategic vision for the agriculture industry of the future. The vision would focus on the use of renewable bioproducts to supplement use of petroleum-based resources in manufacturing everyday consumer goods, such as plastics, paint, and adhesives. The visioning process brought together over 100 experts from industry, nonprofit organizations, trade asso-

ciations, and academia to provide input to the document. The resulting vision, *Plant/Crop-Based Renewable Resources 2020 – A Vision to Enhance U.S. Economic Security through Renewable Plant/Crop-Based Resource Use*, was published in January 1998.

The vision established a set of long-term, ambitious goals for increasing the use of renewable resources:

- To use plant-derived materials to meet at least 10% of demand for basic chemical building blocks by 2020, with development concepts in place by then to meet 50% of demand by 2050
- To establish a plant/crop-based (crop, forestry, processing) manufacturing infrastructure

THE AGRICULTURE INDUSTRY VISION AND ROADMAP ESTABLISH INDUSTRY-WIDE GOALS AND PERFORMANCE TARGETS...

R&D Opportunity Area	
<div> <div>3</div> <div>SELECTED VISION GOAL</div> </div> <div> Replace at least 10% of basic chemical building blocks with plant-derived renewables by 2020, with development concepts in place to achieve a further increase to 50% by 2050 </div>	<div>Plant Science</div> <ul style="list-style-type: none"> Develop an understanding of gene regulation and control of plant metabolic pathways as well as functional genomics to improve gene manipulation.
	<div>Production</div> <ul style="list-style-type: none"> Improve production methods (e.g., higher plant productivity, more desirable plant components) to ensure that an adequate and cost-effective supply of plants is available for industrial use.
	<div>Processing</div> <ul style="list-style-type: none"> Develop new or modified processes to create chemicals and other products from plants rather than hydrocarbons. Production, separation, and new, more effective catalysts are priority topics.
	<div>Utilization</div> <ul style="list-style-type: none"> Enhance understanding of the relationships between the structure and functionality of different plant constituents (e.g., proteins, starch). Develop a sound infrastructure and distribution systems to ensure an adequate distribution of raw materials.

- To establish collaborative partnerships among industry, government, and academia for the R&D needed to achieve market opportunities and ensure that processes and systems are commercially viable

PLANT/CROP-BASED RENEWABLE RESOURCES INDUSTRY ROADMAP

In 1998, the manufacturing and growing partners that contributed to the vision formed an Executive Steering Group, made up of industry leaders from several key companies and associations, to oversee and guide the road-mapping process. The steering group developed the *Technology Roadmap for Plant/Crop-Based Renewable Resources 2020*, which identifies the critical R&D pathways necessary to achieve the goals of the vision. With input from over 120

industry experts and professionals, the steering group developed a strategy for optimizing the combined R&D efforts of the agriculture, forest products, life science, and chemical industries.

The roadmap defines both short- and long-term R&D priorities that will lead to the development of a reliable renewable resource base for the future. The R&D priorities target four barrier areas:

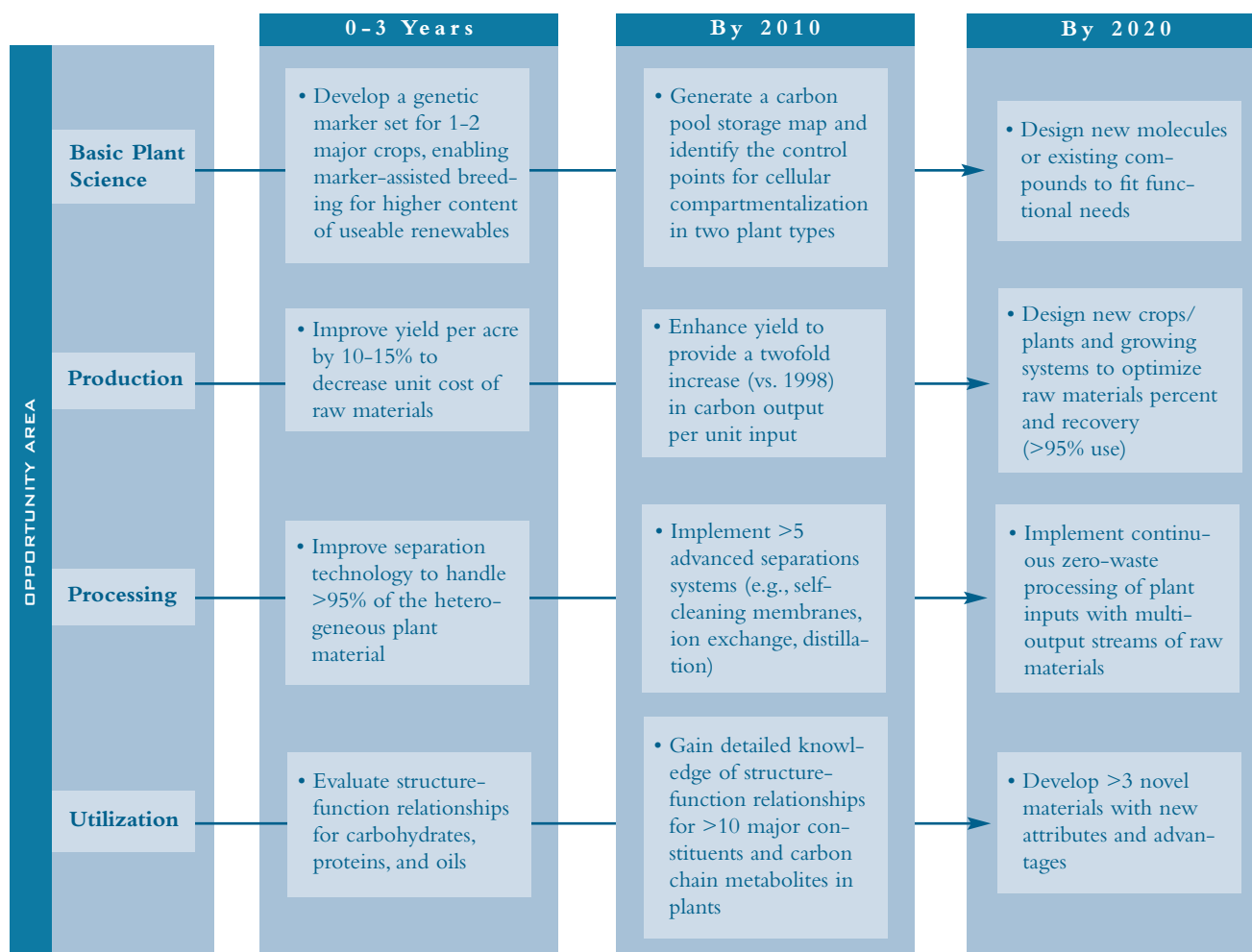
- Plant Science
- Production
- Processing
- Utilization

Within these areas, the agriculture, forest products, life science, and chemical industries will work together in a coordinated manner to advance renewable resource utilization.

PLANT/CROP-BASED RENEWABLE RESOURCES VISION

Provide continued economic growth, healthy standards of living, and strong national security by developing plant/crop-based renewable resources as a viable alternative to non-renewable fossil fuels.

...AND IDENTIFY RESEARCH TO ACHIEVE THOSE TARGETS.



PARTNERSHIP YIELDS AWARD-WINNING COMMERCIAL SUCCESS

In June 1998, an OIT R&D project received both the 1998 Presidential Green Chemistry Challenge Award and the Discover Magazine Award for Technical Innovation for a process used to produce chemical solvents from corn.

This new, fermentation-based process was developed by scientists from Argonne National Lab and co-funded by and licensed to NTEC, Inc., through a CRADA. The process uses advanced membranes, catalysts, and electrical energy to cost-effectively convert corn starch directly into ethyl lactate using only one-tenth the energy of traditional production and without producing great amounts of waste.

Jim Frank, project director at Argonne National Lab, notes, "Without OIT's continued support for this high-risk project over a period of several years, success would not have been possible. Government is playing a critical role in supporting development of promising, high-risk, pre-competitive technologies."

The Department of Energy invested \$500,000 annually over five years to develop this new process—a process that could result in \$12 billion per year in gross sales of corn-based solvents.

Team & Partnership Activities

OIT's Agriculture Team facilitates the public-private partnerships of the Industries of the Future initiative. Industry and government collaboratively pursue precompetitive R&D that will enhance energy security, minimize environmental impacts, and promote economic well-being.

NEW PORTFOLIO PROJECTS

In August 1999, the Agriculture Team awarded six R&D projects from its first competitive solicitation to help achieve the targets of the strategic vision, *Plant/Crop-Based Renewable Resources 2020*. The solicitation sought projects that would reduce energy use in agricultural and related industries, as well as enhance U.S. economic competitiveness. Specifically, the R&D projects were required to address high-priority research needs identified in the Processing and Utilization categories of the technology roadmap.

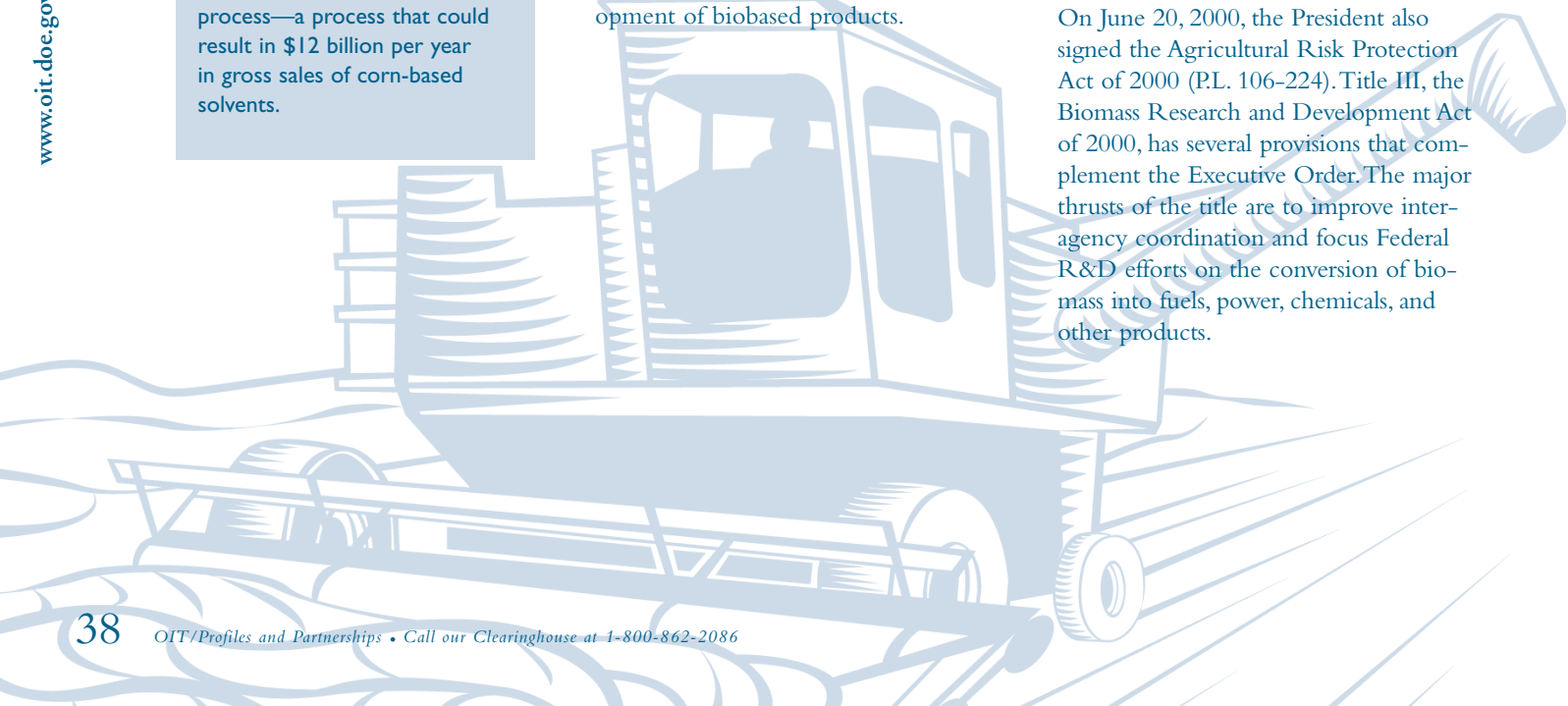
OIT's Agriculture Team also leverages the related work of other OIT Industries of the Future teams, such as Chemicals and Forest Products, since the inputs and products of those industries play an integral role in the development of biobased products.

BIOENERGY INITIATIVE

Integrating efforts and leveraging resources will help the Agriculture Team to achieve the far-reaching goals of the vision, reduce reliance on imported oil, and rejuvenate the nation's rural communities. One such effort is supporting the President's 1999 Executive Order 13134 on developing and promoting biobased products and bioenergy. This Presidential Initiative is stimulating public-private partnerships and accelerating the use of biomass as a feedstock for industrial chemicals and other products, power generation, and transportation fuels.

In his Executive Order, the President directed the Executive Branch to achieve greater cohesion and focus in this area. In a memorandum accompanying the Order, the President set a goal of tripling U.S. use of biobased products and bioenergy by 2010. Reaching this goal would generate billions of dollars in new income for farmers, create employment opportunities in rural communities, and reduce greenhouse gas emissions by as much as 100 million tons a year—the equivalent of taking more than 70 million cars off the road.

On June 20, 2000, the President also signed the Agricultural Risk Protection Act of 2000 (P.L. 106-224). Title III, the Biomass Research and Development Act of 2000, has several provisions that complement the Executive Order. The major thrusts of the title are to improve inter-agency coordination and focus Federal R&D efforts on the conversion of biomass into fuels, power, chemicals, and other products.

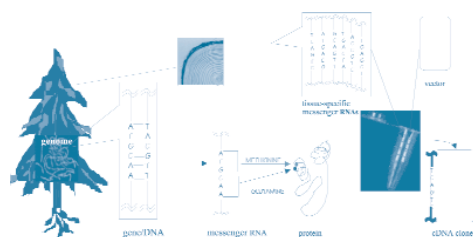


REPRESENTATIVE AGRICULTURE-RELATED PROJECTS IN OIT'S PORTFOLIO

	PLANT SCIENCE & PRODUCTION	PROCESSING	UTILIZATION	ENERGY	ENVIRONMENT	RECYCLING
Agriculture Team						
•Biocatalysis under Extreme Conditions		●		●		
•Biodesulfurization of Gasoline		●			●	
•Catalytic Upgrading of Glucose to Chemicals		●	●			
•Chemicals from Lignocellulose		●				
•Clean Fractionization – Inexpensive Cellulose for Plastics Production		●	●			
•Utilization of Corn-Based Polymers			●			
•Development of Selective Surface Flow Membranes		●				
•Efficient Compressed Air Systems				●		
•Efficient Motor Systems				●		
•Electrodeionization for Product Purification		●				●
•Energy and Waste Audits				●	●	●
•Esters from Bio-based Feedstocks		●				
•Fractionation of Corn Fiber for the Production of Polyols		●	●			
•High-Performance Steam Systems				●		
•Improved Catalytic Enzymes		●				
•Low Temperature Catalytic Gasification of Aqueous Process Streams		●			●	●
•Low-NOx Turbine Retrofits				●	●	
•Pine Gene Discovery Project	●					
•Plastics, Fibers, and Solvents from Bio-derived Acids		●	●			
•Precision Farming	●			●	●	
•Production of Succinic Acid from Biomass		●				
•Products from Wheat Milling		●	●			
•Reactor/Separator for Ethanol from Cellulose		●				
•Recovery and Water Recycling Using Hydrogels		●				●
•Soy-Based Two-Cycle Engine Oils			●			
•Trees Containing Built-in Pulping Catalysts	●					

See "Selected Agriculture Portfolio Highlights" on the next two pages for additional information

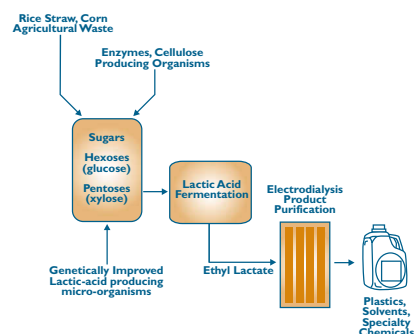
Selected Agriculture Portfolio Highlights



Sets of genes can be expressed to produce proteins with specific cellular functions (e.g., disease resistance).

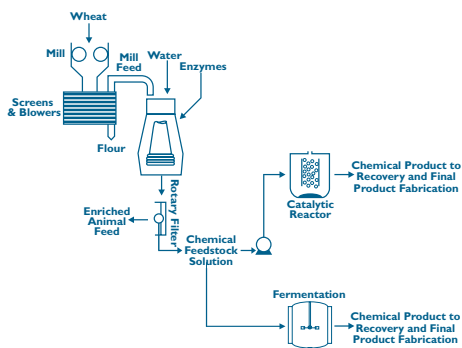


Precise farming tools will reduce energy use, conserve water, and minimize use of pesticides and fertilizers.



Creating chemicals from rice and corn will expand agricultural markets and conserve oil resources.

AREA	PLANT SCIENCE & PRODUCTION	PRODUCTION	PROCESSING
PROJECT	Pine Gene Discovery Project	Precision Farming	Chemicals from Lignocellulose
DESCRIPTION	<p>Although gene sequencing research for major agricultural plants is already underway, there is a lack of fundamental information on genes in woody plants. Access to a catalog of loblolly pine genes will be an important asset for forestry researchers, allowing studies on the genetic engineering of improved tree lines and other ways of improving plant stocks. By identifying a large number of partial gene sequences in woody plants, the project partners will open up new scientific and commercial opportunities for the forestry industry.</p> <ul style="list-style-type: none"> • Catalogs pine genes useful in industrial research • Expands knowledge base for identifying problems in pine physiology • Advances biological information on the similarity of genes among major taxonomic groups of plants and animals 	<p>This process will allow agriculture producers to have commercial access to an integrated system of precision farming tools that will enable farmers and consultants to assess field conditions, create management zone maps, and control applications in small sections with irrigation pivots. Also, the Accu-Pulse system software-based data collection methods that produce GIS layers of information about variations in water, nutrients, vegetative material, and pests will be integrated into the system. If used on 10–15% of irrigated farmlands in the U.S.:</p> <ul style="list-style-type: none"> • Saves significant amounts of energy in crop production • Significantly reduces chemical and energy use 	<p>Researchers are integrating two approaches to utilizing waste agricultural feedstocks by converting wood waste and rice straw to mixed sugars, fermenting the sugars to produce lactic acid, and chemically converting the acid to lactic esters. Lactic esters can serve as solvents or raw material for chemicals and polymers, replacing some of the petroleum-derived end-products.</p> <ul style="list-style-type: none"> • Expands the use of agricultural feedstocks • Enhances national energy security • Serves a \$5 billion U.S. market
PARTNERS	<p>California State University – Hayward North Carolina State University University of Minnesota Georgia-Pacific Corp. Rayonier Corp. Union Camp Corp. Westvaco Corp.</p>	<p>Colorado Corn Administration of Lakewood, CO Colorado Office of Energy Management</p>	<p>Argonne National Laboratory BC International Corporation California Institute of Food and Agricultural Research Collins Pine Company NTEC-Versol</p>



A new process will reduce wheat milling by-products by 50% while creating new feedstocks for chemicals.



Enhancing the properties of corn-based polymers will increase use of bioproducts.



Marine oil from soybeans is environmentally friendly.

PROCESSING

Products from Wheat Milling

Mill feed (the product of wheat flour milling) is currently used as a low-value animal feed, but researchers are developing processes to recover the starch component for use as a feedstock in valuable chemicals. Converting starch will reduce by-product waste by 50% and provide an energy-efficient feedstock for chemicals such as sugar alcohols (sorbitol, mannitol) and polyols (propylene glycol), and for the food, cosmetic, and plastic industries.

- Decreases emissions of CO₂, SO₂, NO_x, particulates, and VOCs
- Replaces petroleum as a feedstock for chemicals
- Significantly reduces the amount of electricity and petroleum in processing

UTILIZATION

Enhanced Utilization of Corn

Project partners are examining the structure—physical/chemical property relationship—of poly (lactic acid) (PLA), a biodegradable plastic, in order to improve the processing ability of PLA. Ultimately, this will allow for new materials with improved properties, expanding the application of PLA to areas such as hybrid paper-plastic packaging.

- Utilizes renewable source as feedstock
- Reduces landfill volumes
- Removes greenhouse gases from atmosphere

UTILIZATION

Soy-Based 2-Cycle Engine Oils

About 15 million gallons of oil are consumed by the recreational boating sector in North America. Researchers want to develop, test, and screen a series of 2-cycle engine oils based on vegetable oils for use in water-cooled engines that will offer the same performance as petroleum-based products without harming the environment.

- Saves 7.5 million gallons of petroleum annually
- Offers a 90-100% biodegradable product
- Produces fewer emissions
- Increases fire safety
- Extends engine life

Mennel Milling Company
Pacific Northwest National Laboratory
Pendleton Flour Mills, Inc.

Cargill Dow Polymers, LCC
Colorado School of Mines
National Renewable Energy Laboratory

Omni Tech International, Ltd.
Smith, Bucklin & Associates
Terresolve Technologies, Ltd.
United Soybean Board